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Effect of Arbuscular Mycorrhiza Fungal Inoculation with Compost on Yield and P Uptake of Wheat in Alkaline Calcareous Soil

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Abstract

An experiment was conducted in pots under natural conditions in alkaline calcareous soil to determine wheat (*Triticum aestivum* L. c.v. Atta Habib) yield and P uptake as influenced by Arbuscular mycorrhizal fungi (AMF) inoculation with compost prepared from fresh animal dung and rock phosphate. Data indicated that wheat grain, shoot and roots yields increased significantly ($P \leq 0.05$) by inoculation of commercial mycorrhiza (AMF-II) and half dose of compost. Grain yield increased by 43% and 37%, shoot by 43% and 39% and roots yield by 51% and 45% over control of N and K fertilizers. Straw yield was maximum as 5075 kg·ha^{-1} in the treatment of AMF-II inoculation with full dose of compost, which was significantly ($P \leq 0.05$) higher as 44% and 40% over control of N and K fertilizers. Maximum and significantly ($P \leq 0.05$) higher plant N and P uptake by wheat were observed in the treatment inoculated by indigenous mycorrhiza (AMF-I) with full dose of compost followed by the inoculation of AMF-II with full dose of compost and SSP treatment. Maximum and significantly ($P \leq 0.05$) increased soil spores' density of AMF by 26 spores per 20 g soil with maximum roots infection intensity in wheat were observed by the inoculation of AMF-I with full dose of compost. The AMF-II is slightly better than AMF-I regarding grain, shoot and root yield, whereas AMF-I is better in N, P uptake, soil spore density and their root infection intensity than AMF-II. Alone inoculation and compost application increase the yield and nutrients uptake but the highest improvement was observed with inoculation of AMF with compost. Results suggest that inoculation of AMF with compost has potential to improve wheat yields and plants' P uptake under given soil conditions.

Keywords

AMF Inoculation, Compost, Yield, Phosphorus Uptake, Wheat Crop and Alkaline, Calcareous Soil

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1. Introduction

Mycorrhiza is the root fungi, which makes symbiotic association with roots of most crops and forest trees. The prominent parts of Arbuscular mycorrhiza fungi are hyphae, arbuscules and vesicles. The hyphae are non-septate when young ramify within the cortex. The arbuscules, lying in the root cells of the plant, are mainly responsible for transfer of nutrients from fungus to plants. However, root internal hyphae can also release nutrients to the host plant. The vesicles are storage structures of mycorrhiza found in many fungal species.

Mycorrhiza enhances growth of the plants by increased absorption of water and nutrients from soil [1]. The enhanced P uptake is generally regarded as the most important benefit that AMF provides to their host plant and soil P status is often the main controlling factor in the plant—fungal relationship [2]. It has been reported that under high P concentrations there is a poor relationship between mycorrhiza and host plant but under poor soil P condition the mycorrhiza helps to supply soil P to plants [3]. Along with soil, plant and climactic conditions, the effectiveness of AMF in supplying the P from soil to plants and their infectivity, showing the relationship of AMF with host plant may also depend on type and species of AMF. The inoculation of various AMF isolated from different soils and sources may vary in term of effectiveness and their infectivity [4]. The P in Pakistani soil is usually very low and about 80% to 90% of soils are deficient in P [5]. The low P in these soils could be associated with higher lime contents, low organic matter and alkaline soil conditions [6]. Different sources of P could be applied to soil to supplement the soil P and improve the crop yields. These sources may include the organic P sources, synthesized chemical P fertilizer and natural rock phosphate minerals [5]. However, the P release from these sources and resultant response of crops varies with soil and climatic conditions and crop species. The rock phosphate (RP) minerals though are natural and more economical but are not widely applied due to their low solubility and poor crop response in most soil conditions. The agronomic performance of RP is associated with type of RP, plant species, cropping system and soil and climatic conditions of the area. However, pretreatments of RP with organic sources can enhance the P solubility and its releases [7]. The increase in solubility of RP with organic manures could be associated with release of various organic acids and microbial activity that occur during the decaying process [7]. The process of conversion of organic sources into weathered and mineral nutrient components through microbial decay is called composting. The application of these composts has several advantages over non-decomposed fresh organic sources and inorganic synthetic fertilizers. Composts are environment friendly and cost effective technique of waste recycling [8]. They are prepared from roots, leaves, straw, stems and crop residues through microorganism's action. These materials undergo decomposition under adequate moisture and temperature either in open air, heaps or dumped pits. The final products with brown to dark brown material with no odd smell is obtained in about 3 to 6 months depending on various factors like the moisture, temperature, starter dose, C:N ratio, and type and specie of the decomposing microbial population. Composts are usually enriched with different kinds of nutrients like N, P, S and micronutrients to not only speed up the process but also to improve the quality of composts in terms of nutrient concentrations. The enrichment of composts with RP is more appealing as it is cost effective and usually more effective over direct application of RP to soil [7]. Keeping in view of importance of AMF, composting and enrichment of compost with RP, this study was conducted to evaluate the locally extracted AMF and commercially available AMF on the growth and N, P uptake by wheat crop when applied alone or in combination with RP enriched composts.

2. Materials and Methods

An open air pot experiment was conducted to determine yield and P and N uptake by wheat (*Triticum aestivum* L. c.v. Atta Habib) as influenced by two different AMF sources applied with and without RP enriched compost. The treatments were arranged in CRD design with three replications. Strongly calcareous (19% lime), and alkaline (pH; 7.90) soil (0 - 30 cm) soil with silt loam texture was collected from Research Farm of the University of Agriculture, Peshawar and filled in pots at the rate of 3 kg^{-1}. Mycorrhizal spores extracted from 100 g fresh soil of sorghum crop grown for the production of AMF inoculum in the same soil and climatic conditions were used as indigenous inoculum (AMF-I). This indigenous AMF inoculum was dominated with *Glomus intraradices*, where as the spores of *G. fasiculatum* and *G. mossea* were present in minor quantities. These spores were inoculated uniformly in the pots of AMF inoculation at the rate of 100 spore pot^{-1}. The commercial AMF (AMF-II) inoculum was received from BioMyc^{TM}, Germany which consisted species of *Glomus intraradices.* This inoculum was inoculated at the rate of 10 $ml \cdot pot^{-1}$ by the method as described by BioMyc Environment GmbH, Germany [9]. RP enriched compost was prepared from the fresh animal dung and rock phosphate (RP) collected from Hazara area. Fresh animal dung was mixed with RP at the ratio of 2:1 (Dung:RP) according to the method as described by FAO [10]. Dose of N as urea applied at the rate of 60 mg·N·kg^{-1} (120 kg·N·ha^{-1}), P was applied as SSP or RP enriched compost at the rate of 45 mg·P·kg^{-1} (90 kg P_2O_2·ha^{-1}) and K as sulfate of potash (SOP) with rate of 30 mg·K·kg^{-1} (60 kg K_2O·ha^{-1}). All P and K fertilizers were applied at sowing time while N was applied in equal three split doses at sowing, booting and flowering stages. Ten seeds of wheat were sown initially in each pot and were thinned to five plants pot^{-1} after germination. Pots were rearranged after every week to minimize the side effect. All agronomic practices were strictly followed uniformly throughout the growing season for optimum crop growth. Plants were grown up to 90 days of maturity stage. The post harvest grain, shoot and straw yield of wheat were recorded in each treatment after drying. P in plants samples was determined after wet digestion as described by Walsh [11], while N was by Kjeldah Method [12]. To avoid the effect of dilutions or concentrations caused by variation in wheat biomass, the N and P concentrations were converted into total amount of nutrients uptake plants by multiplying nutrient concentrations with total dry matter in kg ha^{-1} according to the procedure as described by Barber [13]. Roots of plants were removed from the soil, washed and dried at 65˚C - 70˚C till constant weight and root dry weights were recorded. Fresh soil and roots samples were also collected and stored at 4˚C for the determination of spores density and AMF root infection intensity. The AMF spores were isolated from soil by wet-sieving and decanting techniques as described by Brundrett [14]. Infection intensity of AMF in the roots was determined according to the procedures of Philips and Hayman [15] and Koske and Gemma [16]. The presences of vesicles, arbuscules were measured by the techniques as described by Giovannetti and Mosse [17]. Isolated spores were identified according to the procedure described by Schenck and Parez [18]. The soil samples were also analyzed for total N determined through kjeldhal method of Bremner [19] and AB-DTPA extractable P by Soltanpour and Schwab [20]. All the data were statistical analyzed through ANOVA technique and the means were compared by LSD test [21].

3. Results and Discussions

The results on yielding parameters, AMF spore density and root infectivity, and nutrient concentration in soil and plants as influenced by the given AMF inoculum sources and RP enriched compost is given in the following lines.

3.1. Wheat Yield and Yield Components

The ANOVA revealed that grain shoot, root and straw yields were significantly enhanced over control with application of RP enriched compost, and both sources of AMF inoculated alone or in combination with composts at both levels (**Table 1**). When inoculated alone, both AFM-I and AFM-II produced significantly higher values of these parameters over control but were statistically similar with each other. For example the AMF-I produced the grain yield of 3000 kg·ha^{-1} and AFM-II yielded 2930·kg^{-1} wheat grain·ha^{-1} which were higher by 30% and 27%, respectively over control. The inoculation of both AMF with combination of compost at levels of half (2250 kg·ha^{-1}) and full (4500 kg·ha^{-1}) further enhanced its role in increasing the growth and yield of wheat crop. Sharif *et al.* [22] reported similar results where they observe higher shoot and root dry mater yields of wheat crop with inoculation of AMF alone and in combination with poultry manure (PM), farmyard manure (FYM) and humic acid (HA). Combining AMF-I and AMF-II with half compost produced yield of 3150 and 3300 kg·ha^{-1} which were 37% and 43 % higher than control. This difference in case of yield was statistically similar but AMF-II with half dose of compost produced significantly higher shoot, root and straw weights of 8360, 1371 and 5060 kg·ha^{-1} than AFM-I with values of 7916, 2183 and 4766, respectively. Interestingly, the AMF-I was slightly superior than AFM-II when applied alone but the AMF-II superseded the AMF-I when applied in combination with compost (**Figure 1** and **Figure 2**). Increasing the compost levels from half to full, the AFM combination did not show significant response, revealing that sufficient amount of P from RP had been provided in case of half dose of compost. It further revealed that the amount of enrich RP could be substantially reduced with application of AMF. When averaged across all levels of composts, the AMF-II was slightly superior to AMF-I in case of all parameters but these differences were too small to be accounted. Such increases in yielding parameters with AMF plus compost have been reported by Habashy *et al.* [23]. El-Goud [24] also observed higher yield of maize plants with AMF and compost application. They reported the highest yields for the treatments receiving inoculation of AMF with the application of 75% (3.6 t·ha^{-1}) compost and 100% N of recommended dose of nitrogen fertilizer. El-Sayed *et al.* [25] also reported similar higher yield of maize with applica-

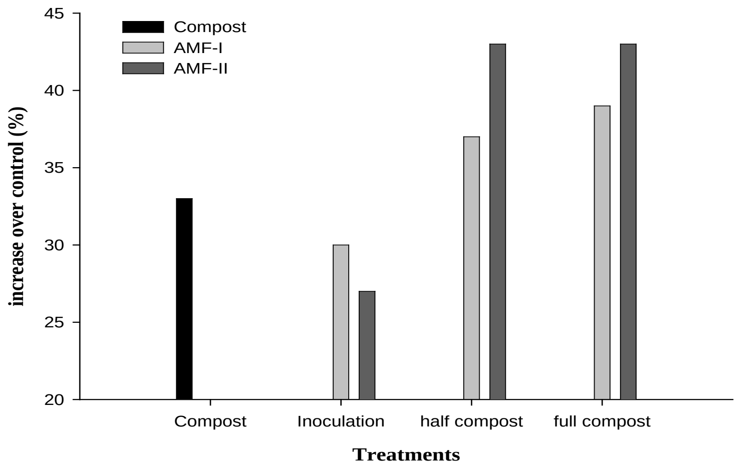

Figure 1. Percent increased in wheat grain yield as affected by AMF inoculation with compost over control.

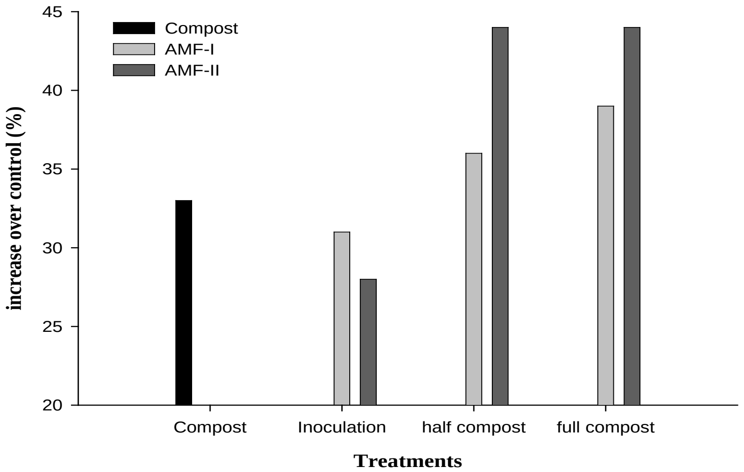

Figure 2. Percent increased in wheat shoot dry matter as affected by AMF inoculation with compost over control.

Table 1. Grain, shoot, root and straw yield of wheat as affected by AMF inoculation with compost.

Treatments	Grains	Shoot	Roots	Straw
	yield ($kg \cdot ha^{-1}$)			
Control (No fertilizer)	2300 e*	5820 f*	1566 c*	3520 e*
N and K fertilizer (basal dose)	2400 e	6000 f	1633 c	3600 e
Full dose of compost	3050 bcd	7750 de	2000 b	4700 cd
Indigenous AMF (AMF-1)	3000 cd	7600 e	1993 b	4600 d
Commercial AMF (AMF-II)	2930 d	7450 e	1990 b	4610 d
Half dose of compost + AMF-I	3150 abc	7916 cd	2183 ab	4766 abcd
Half dose of compost + AMF−II	3300 a	8360 a	1371 a	5060 ab
Full dose of compost + AMF-I	3190 ab	8066 bc	2245 ab	4863 abcd
Full dose of compost + AMF-II	3285 a	8360 a	2354 a	5075 a
Full recommended dose of SSP	3270 a	8246 ab	2342 a	4976 abc

*Means with different letter(s) in columns are significantly different at $P \le 0.05$. N-P-K = 120-90-60 $kg \cdot ha^{-1}$, respectively, compost = 4500 $kg \cdot ha^{-1}$, AMF = 70 spores pot^{-1}.

tion of AMF with 75 % (4 t·ha^{-1}) compost of recommended dose and 100% NPK fertilizer application. Duponnois *et al*. [26] stated that inoculation of *G. intraradices* with Kodajari Rock Phosphate (KRP) significantly increased shoot and root growth over the alone inoculation of AMF or RP treatment. The yield parameters of wheat at both sources and levels of compost were comparable to SSP application suggesting that commercially available SSP could be substituted by the combine use of AMF and RP enriched compost. Alone application of RP enriched compost produced statistically higher values of grains, shoot, root and straw over control and N and K fertilizer revealing its role in P supply and improvement in other soil nutrient and properties. However, these values were statistically lower than SSP treated plots and from those receiving any AMF with compost. Similarly, the alone inoculation of AMF was inferior to SSP suggesting that neither alone AMF nor RP enriched compost could produce as much higher yield as SSP.

3.2. Post harvest N, P and Soil Nutrients Contents

The results of post harvest soil total N and AB-DTPA extractable P, Zn, Cu, Mn and Fe contents as affected by AMF inoculation with compost are presented in the following lines. The ANOVA indicated that soil N, P and micronutrients contents were significantly increased over control with application RP enriched compost, and AMF-I and AMF-II inoculated alone or in combination with half and full doses (**Table 2**). Inoculation of both AFM I and AFM-II alone released significantly higher soil nutrients contents over control but were statistically similar with each other. However, AMF-I inoculation with full dose compost slightly enhanced N, P, Zn, Cu, Mn contents over AMF-II inoculation but Fe content was also slight more with the AMF-II with full dose of compost than AMF-I. Goussous and Mohammad [27] reported that indigenous AMF is better than commercial regarding soil N, P and micronutrient contents. Soil N content was increased by 28% and 25%, P by 46% and 34%, Zn by 28% and 22%, Cu by 46% and 37%, Mn by 34% and 32% by AMF inoculation with full dose of compost, while Fe content improved by 15% and 11% with inoculation of AMF-II and full dose of compost, over control and N and K fertilizers. The result showed that the combine inoculation of AMF with compost can release soil nutrients as with P fertilizer, but alone neither inoculation of AMF nor compost application release as much as with P fertilizers. The results of Habashy *et al*. [23] also revealed were that the combined treatments of AMF and compost significantly increase the release of P and micronutrients in the soil. This is may be due to the lowering pH of the soil and favorable air water balance, which shows positive impacts on the yield. Pacovsky *et al*. [28] and Maksoud *et al*. [29] stated that mycorrhiza significantly increased N and P concentration. Duponnois [26] reported that inoculation of *Glomus intraradices* and Kodjari Rock Phosphate (KPR) signify-

Table 2. Soil N, P and micronutrients contents as affected by AMF inoculation with compost.

		AB-DTPA extractable				
Treatments	Total N	P	Zn	Cu	Mn	Fe
	soil contents (mg·kg^{-1})					
Control (No fertilizer)	1123 c*	5.80 d*	1.11 c*	3.70 c*	3.96 c*	3.50 c*
N and K fertilizer (basal dose)	1150 bc	6.33 cd	1.21 b	4.00 c	8.10 c	3.63 bc
Full dose of compost	1173 bc	6.60 cd	1.30 abc	4.23 bc	8.40 bc	3.93 ab
Indigenous AMF(AMF-1)	1236 bc	6.80 cd	1.31 ab	3.41 d	8.56 bc	3.93 ab
Commercial AMF (AMF-II)	1217 bc	6.86 cd	1.31 ab	3.36 de	8.60 bc	3.83 abc
Half dose of compost + AMF-I	1276 b	7.13 c	1.33 ab	5.23 ab	9.70 ab	3.83 abc
Half dose of compost + AMF –II	1275 b	7.26 bc	1.33 ab	3.58 c	10.03 c	3.83 abc
Full dose of compost + AMF-I	1445 a	8.50 a	1.43 a	5.50 a	10.70 a	3.70 bc
Full dose of compost + AMF-II	1297 ab	8.33 ab	1.40 ab	5.38 ab	10.03 a	4.03 a
Full recommended dose of SSP	1238 bc	8.33 ab	1.26 abc	5.30 b	10.60 a	4.03 a

*Means with different letter(s) in columns are significantly different at P ≤ 0.05. N-P-K = 120-90-60 kg·ha^{-1}, respectively, compost = 4500 kg·ha^{-1}, AMF = 70 spores pot^{-1}.

cantly increased N and P concentration in soil over inoculation alone or RP treatment alone.

3.3. Plant N and P Uptake (Table 3, Figures 3-4)

The results of N and P uptake as affected by the inoculation of AMF with compost were presented in the following lines.

The data indicated the P and N uptake were significantly increased over control and N and P fertilizers by inoculation of AMF alone and inoculation of AMF with application of composts at both levels. Sharif *et al.* [22] reported that N uptake by wheat significantly increased with inoculation of AMF alone and in combination with poultry manure (PM), farmyard manure (FYM) and humic acid (HA). Inoculation AMF-I and AMF-II alone significantly increased N and P uptakes but statistically there were no differences. Similarly compost application also enhanced N and P uptake but the highest uptake of N and P uptake of 175 kg·ha^{-1} and 12.89 kg·ha^{-1}, respectively were noted in the treatment receiving inoculation of AMF-I with full dose of compost (**Figure 3** and **Figure 4**), which was significantly ($P \le 0.05$) higher by 78% and 63%, 198% and 150%, respectively over control and N and K fertilizers. With inoculation of AMF-II with full dose of compost N and P uptake of 173 and 12.43 kg·ha^{-1} were recorded which were slightly less than AMF-II inoculation with full dose of compost, but statistically were similar. The results revealed that both AMF-I and AMF-II with full dose of compost were slightly increased over SSP but the differences were too small to be counted. The results suggesting that inoculation of AMF with full dose of compost enhanced N and P uptake statistically similar with that of SSP fertilizer, but neither alone inoculation of AMF nor compost application could improve N and P uptake as much as by application of SSP. El-Goud [24] reported highest uptake of N in the treatment 100% (4.8 t·ha^{-1}) compost and

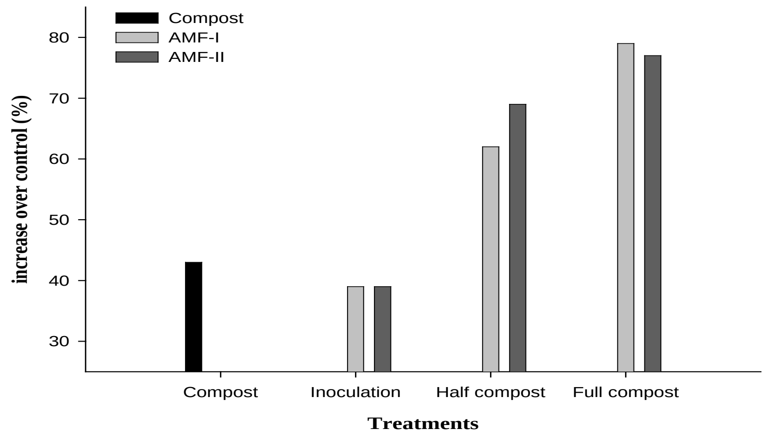

Figure 3. Percent increased in N uptake by wheat as affected by AMF inoculation with compost over control.

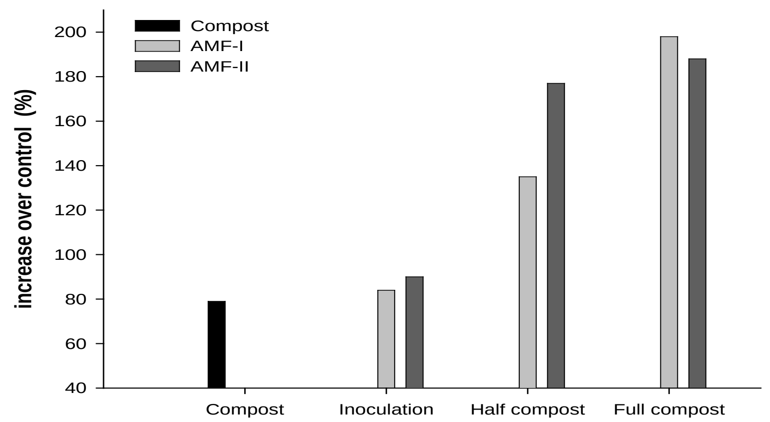

Figure 4. Percent increased in P uptake by wheat as affected by AMF inoculation with compost over control.

Table 3. Plant N and P uptake as influenced by AMF inoculation with compost.

Treatments	N	P
	Plant uptake (kg·ha^{-1})	
Control (No fertilizer)	98 d*	4.32 d*
N and K fertilizer (basal dose)	107 d	5.16 d
Full dose of compost	140 c	7.74 c
Indigenous AMF inoculation (AMF-1)	136 c	7.96 c
Commercial AMF inoculation (AMF-II)	136 c	8.21 c
Half dose of compost + AMF-I	159 b	10.14 b
Half dose of compost + AMF−II	166 ab	11.97 a
Full dose of compost + AMF-I	175 a	12.89 a
Full dose of compost + AMF-II	173 a	12.43 a
Full recommended dose of SSP	168 ab	12.69 a

*Means with different letter(s) in columns are significantly different at $P \leq 0.01$. N-P-K = 120-90-60 kg·ha^{-1}, respectively, compost = 4500 kg·ha^{-1}, AMF = 70 spores pot^{-1}.

100% N inoculated with AMF and maximum P uptake in the treatment 75% (3.6, 4.8 t·ha^{-1}) compost and 100% inoculated with AMF. Lambert *et al.* [30] found that AMF increased uptake of immobile nutrients such as P, Cu and Zn. Chandreshekara *et al.* [31], Al-Karaki and Al-Radad, [32] also reported that AMF can increase absorption of Phosphorus. The study conducted by Maksoud *et al.* [29] indicated that leaf P content was significantly increased by inoculation of AMF with rock phosphate. Habashy *et al.* [23] reported that P uptake increased when organic matter was added to the alkaline calcareous soil and thus may applied organic matter released phosphate in soil and more available to the plant. Sharif and Jan [33] found that the inoculation of AMF with rock phosphate significantly increased the uptakes of N and P.

3.4. Soil Spores Density of AMF and Their Root Infection Intensity (Table 4)

The result of soil spores density of AMF and their root infection intensity in wheat crop as influenced by AMF inoculation with compost is discussed in the following lines.

The ANOVA revealed that soil spores density of AMF and their root infection intensity in wheat were significantly enhanced by the inoculation alone of AMF-I and AMF-II over control, which 20 and 21 spores per 20 g soil and 25%, respectively (**Table 4**). The highest AMF soil spores density 26 spores per 20 g soil and their root infection intensity of 37% were recorded in the treatment of inoculation of AMF-I with full dose of compost which was significantly ($P \leq 0.01$) higher by 73% and 62% and 85% and 76%, respectively over control and N and K fertilizers followed by the treatment of inoculation of AMF-I with half dose of compost. The AMF-I inoculation with compost was slightly better than AMF-II, but statistically similar. Goussous and Mohammad [27] reported that indigenous AMF is better than commercial regarding spore density and root infection intensity and this higher colonization by indigenous AMF indicated that the adaptation of these AMF to their native soil and benefit better their hosts under given soil condition. The results of Castillo *et al.* [34] were similar who found that AMF inoculation enhanced the colonization percentage of host plants.

The result of Habashy *et al.* [23] showed that increased spores density and mycorrhizal root colonization increased gradually with the inoculation of AMF and organic waste compost, while significantly increased with the organic compost alone comparing to control. Koreish *et al.* [35] reported that mycorrhizal root infection increased by application of rock phosphate.

Figure 5 showed that there is positive correlation exists between soil spore density and their root infection intensity. When spores density increases their root infection intensity also increases. Khakpour and Khara [36] found that there is positive correlation between AMF spores and their root infection intensity. Sivakumar [37] reported positive correlation between spores density and root infection intensity.

Arbuscular mycorrhizal fungi form symbiotic association with most plant species. These fungi enhance uptake of relatively immobile nutrients particularly phosphorus and other micronutrients. P is the second essential macro nutrient after nitrogen required for the growth of plant and found in organic and inorganic form. Due to

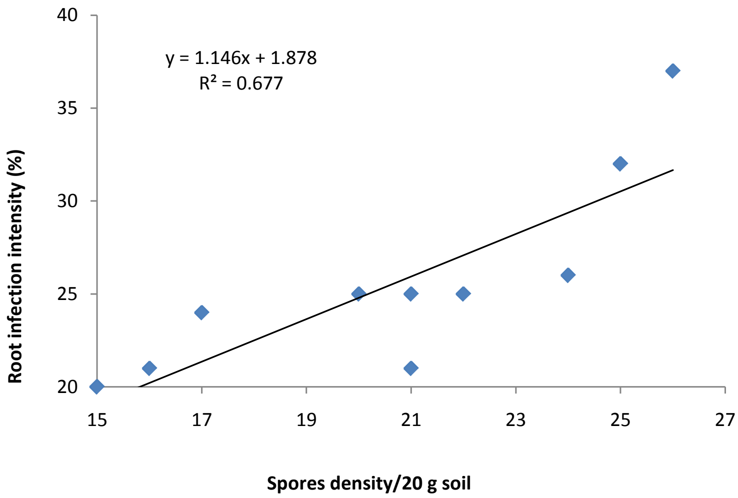

Figure 5. Relationships between soil spores density of AMF and their roots infection intensity in wheat.

Table 4. Soil spores density and roots infection intensity in wheat crop as affected by AMF inoculation with compost.

Treatments	AMF spores density	AMF root infection intensity
	(20 g soil)	(%)
Control (No fertilizer)	15 e *	20 d*
N and K fertilizer (basal dose)	16 e	21 d
Full dose of compost	17 e	24 cd
Indigenous AMF (AMF-1)	20 d	25 c
Commercial AMF (AMF-II)	21 cd	25 c
Half dose of compost + AMF-I	25 ab	32 ab
Half dose of compost + AMF-II	24 ab	26 c
Full dose of compost + AMF-I	26 a	37 a
Full dose of compost + AMF-II	22 bc	25 c
Full dose of SSP	21 cd	21 cd

*Means with different letter(s) in columns are significantly different at $P \leq 0.01$; N-P-K = 120-90-60 kg·ha^{-1}, respectively, compost = 4500 kg·ha^{-1}, AMF = 70 spores pot^{-1}.

its low solubility and mobility plant cannot utilize P is an in organic or complex form [38]. Inorganic P present in the soil, which is readily available to the plant, but in limited amount. Thus AMF enhance the nutrient uptake through its external hyphae into the surrounding soil and hydrolyzed unavailable source of phosphorus with the help of secreted enzymes such as phosphate [39]. Arbuscular mycorrhizal fungi dissolve relatively insoluble nutrients more efficiently even from very low nutrient concentration because of their ability to produce organic acids, exploration of more area beyond the root zone and release of CO_2. Mycorrhizal fungi are beneficial symbiotic microorganisms with their extra metrical hyphae, which increase growth and yield of most crops. These fungi improve soil structure and thus enhance physically, chemically and biological soil quality. Mycorrhiza play significant role in the uptake of P from Rock phosphate (RP) and mycorrhizal plants are more effective in the utilization of RP than non-mycorrhizal plants and it is being the cheapest source of P, can be best utilized as P fertilizer only when it is dissolved properly by chemical or biological means.

4. Conclusion

Inoculation of AMF with compost has the potential to improve the yield and nutrients uptakes by wheat under the given soil conditions. The statistically similar results of inoculation of AMF with compost and NPK (SSP) treated pots indicated that the efficiency of RP could improve with AMF inoculum. This will in return reduce the input cost of farmer and help natural resource management by utilizing the natural occurring RP. The non-significant differences between the AMF with full compost and half compost suggested that crop growth could be improved in both cases.

References

[1] Singh, B.C.I. (2003) Effect of Vesicular-Mycorrhizal Inoculation at Different Soil P Availability on Growth and Nutrient Uptake. *Agriculture*, *Ecosystem and Environment*, **58**, 225-124.

[2] Smith, S.E. and Read, D.J. (1997) Mycorrhizal Symbiosis. Elsevier Science, New York.

[3] Sharif, M., Sarir, M.S. and Nasrullah (2005) Arbuscular Mycorrhizal Incidence and Infectivity of Wheat and Maize Crops. *Soil and Environment*, **24**, 145-151.

[4] Jakobsen, T. and Nielsen, N.E. (1983) Vesicular Arbuscular Mycorrhiza in Field-Grown Crops, 1. Mycorrhizal Infection in Cereals and Peas at Various Times and Soil Depths. *New Phytologist*, **93**, 401-413. http://dx.doi.org/10.1111/j.1469-8137.1983.tb03440.x

[5] Meman, K.S., Rashid, A. and Puno, H.K. (1996) Phosphorous Difficiency Diagnosis and P Soil Test Calibration in Pakistan. *Proceeding of the Topsoils Phosphorous Decision Support System Workshop*, Taxas, 11-12 March 1992, 117-139.

[6] Manzoor, A. (2012) Critical Soil Solution Phosphorus Concentrations Essential for Plant Growth in Calcareous Soil Series. Ph.D. Thesis, The University of Agriculture, Peshawar.

[7] Matiullah, K. (2012) Enhancement of Phosphorus Solubilization from Indigenous Rock Phosphate through Organic Materials and Its Effect on Crops. Ph.D. Thesis, The University of Agriculture, Peshawar.

[8] Millner, P.D., Sikora, L.J., Kaufman, D.D. and Simpson, M.E. (1998) Agricultural Uses of Biosolids and Other Recyclable Municipal Residues. USDA Agricultural Research Service Conservation Research Report, 9-38.

[9] BioMyc™ (2010) Production of AMF Spores and Hyphae. BioMycorrhizal Environment GmbH, Germany. http://www.biomyc.de/

[10] FAO (1977) Recycling of Organic Wastes in Agriculture Soil Bull, 40. FAO, Rome.

[11] Walsh, L.M. and Beaton, J.D. (1977) Soil Testing and Plant Analysis. Soil Science Society of America, Inc., Wisconsin.

[12] Ryan, M.H., Norton, R.M., Kirkegaard, J.A., McCormick, K.M., Knights, S.E. and Angus, J.F. (2002) Increasing Mycorrhizal Colonisation Does Not Improve Growth and Nutrition of Wheat on Vertosols in South-Eastern Australia. *Australian Journal of Agricultural Research*, **53**, 1173-1181. http://dx.doi.org/10.1071/AR02005

[13] Barber, S.A. (1995) Soil Nutrient Bioavailability: A Mechanistic Approach. John & Wiley Sons, Inc., New York.

[14] Brundrett, M.C. (1991) Mycorrhizas in Natural Ecosystems. Academic Press, Inc., San Diego.

[15] Phillips, J.M. and Hayman, D.S. (1970) Improved Procedures for Clearing Roots and Staining Parasitic and Vesicular-Arbuscular Mycorrhizal Fungi for Rapid Assessment of Infection. *Transactions of the British Mycological Society*, **55**, 158-161. http://dx.doi.org/10.1016/S0007-1536(70)80110-3

[16] Koske, R.E. and Gemma, J.N. (1989) A Modified Procedure for Staining Roots to Detect VA Mycorrhizas. *Mycological Research*, **92**, 486-488. http://dx.doi.org/10.1016/S0953-7562(89)80195-9

[17] Giovannetti, M. and Mosse, B. (1980) An Evaluation of Techniques for Measuring Vesicular Arbuscular Mycorrhizal Infection in Roots. *New Phytologist*, **84**, 489-500. http://dx.doi.org/10.1111/j.1469-8137.1980.tb04556.x

[18] Schenck, N.C. and Perez, Y. (1990) Manual for Identification of Vesicular Arbuscular Mycorrhizal Fungi (INVAM). University of Florida, Gainesville.

[19] Bremner, J.M. and Mulvaney, C.S. (1996) Nitrogen-Total. In: Miller, R.H. and Keenay, D.R., Eds., *Methods of Soil Analysis*, 22nd Edition, Agron, 595-621.

[20] Soltanpour, P.N. and Schwab, A.P. (1977) A New Soil Test for Simultaneous Extraction of Macro- and Micro-Nutrients in Alkaline Soils 1. *Communications in Soil Science & Plant Analysis*, **8**, 195-207. http://dx.doi.org/10.1080/00103627709366714

[21] Steel, R.G.D. and Torrie, J.H. (1980) Principles and Procedures of Statistics, a Biometrical Approach. McGraw-Hill Kogakusha, Ltd., Tokyo.

[22] Sharif, M., Sarir, M.S., Bakht, J., Saud, S., Ali, A. and Ahmad, M. (2009) Response of Wheat to the Inoculation of Arbuscular Mycorrhizal Fungi in Salt Affected Soil. *Sarhad Journal of Agriculture*, **25**, 209-216.

[23] Habashy, N.R., El-Khair, A.W.A. and Zaki, R.N. (2008) Effect of Organic and Bio-Fertilizer on Phosphorus and Some Micronutrients Availability in a Calcareous Soil. *Research Journal of Agricultural and Biological Science*, **4**, 545-552.

[24] El-Goud, A.K.S.A. (2010) Effect of Endomycorrhizal Fungi and Compost on the Yield and Quality of Maize and Sunflower Plants in Poor Nutrients Soil. Ph.D. Thesis, University of Kassel, Kassel.

[25] El-Sayed, S.E.M., Ramadan, H.M. and El-Fayoumy, M.E. (2006) Impact of Compost and Mineral Fertilizers Application on Cereal Crops in Calcareous Soil. *Menofia Journal of Agricultural Research*, **31**, 1067-1085.

[26] Duponnois, R., Colombet, A., Hien, V. and Thioulouse, J. (2006) Mycorrhizal Fungus and Rock Phosphate Amendment Influence Plant Growth and Microbial Activity in Rhizosphere of *Acacia holoseriea*. *Soil Biology and Biochemistry*, **37**, 1460-1468. http://dx.doi.org/10.1016/j.soilbio.2004.09.016

[27] Goussous, S.J. and Mohammad, M.J. (2009) Comparative Effect of Two Arbuscular Mycorrhizae and N and P Fertilizers on Growth and Nutrient Uptake of Onions. *International Journal of Agriculture & Biology*, **11**, 463-467.

[28] Pacovsky, R.S., Bethlenfalvay, G.J. and Paul, E.A. (1986) Comparisons between P-Fertilized and Mycorrhizal Plants. *Crop Science*, **26**, 151-156. http://dx.doi.org/10.2135/cropsci1986.0011183X002600010035x

[29] Maksoud, M.A., Haggag, L.F., Azzay, M.A. and Saad, R.N. (1994) Effect of VAM Inoculation and Phosphorous Application on Growth and Nutrient Content (P and K) of *Tamarindus indica* L. (Tamarind) Seedlings. *Annals of Agricultural Science*, **30**, 355-363.

[30] Lambert, D.H., Baker, D.E. and Cole, H. (1979) The Role of Mycorrhizae in the Interactions of Phosphorus with Zinc, Copper, and Other Elements. *Soil Science Society of America Journal*, **43**, 976-980. http://dx.doi.org/10.2136/sssaj1979.03615995004300050033x

[31] Chandreshekara, C.P., Patil, V.C. and Sreenivasa, M.N. (1995) VA-Mycorrhiza Mediated P Effect on Growth and Yield of Sunflower (*Helianthus annus* L.) at Different P Levels. *Plant and Soil*, **176**, 325-328. http://dx.doi.org/10.1007/BF00011797

[32] Al-Karaki, G.N. and Al-Raddad, A. (1997) Effects of Arbuscular Mycorrhizal Fungi and Drought Stress on Growth and Nutrient Uptake of Two Wheat Genotypes Differing in Their Drought Resistance. *Mycorrhiza*, **7**, 83-88. http://dx.doi.org/10.1007/s005720050166

[33] Sharif, M. and Jan, B. (2008) Growth and Nutrient Accumulation of Maize Plants as Affected by the Inoculation of AMF with Rock Phosphate. *Soil and Environment*, **27**, 116-122.

[34] Castillo, P., Nico, A.I., Azcon-Aguilar, C., Del Rio Rincon, C., Calvet, C. and Jimenez-Diaz, R.M. (2006) Protection of Olive Planting Stocks against Parasitism of Root-Knot Nematodes by Arbuscular Mycorrhizal Fungi. *Plant Pathology*, **55**, 705-713. http://dx.doi.org/10.1111/j.1365-3059.2006.01400.x

[35] Koreish, E.A., El-Fayoumy, M.E. and Ramadan, M.E. (1998) Contribution of Vesicular Arbuscular Mycorrhiza and Phoshorin in Acquisition of Phosphorus and Micronutrient by Maize (*Zea mays*, L.) in a Calcareous Soil. *Egypt Journal of Soil Science*, **38**, 101.

[36] Khakpour, O. and Khara, J. (2012) Spore Density and Root Colonization by Arbuscular Mycorrhizal Fungi in Some Species in the Northwest of Iran. *International Research Journal of Applied and Basic Sciences*, **3**, 977-982.

[37] Sivakumar, N. (2013) Effect of Edaphic Factors and Seasonal Variation on Spore Density and Root Colonization of Arbuscular Mycorrhizal Fungi in Sugarcane Fields. *Annals of Microbiology*, **63**, 151-160. http://dx.doi.org/10.1007/s13213-012-0455-2

[38] Schachtman, D.P., Reid, R.J. and Ayling, S.M. (1998) Phosphorus Uptake by Plants: From Soil to Cell. *Plant Physiology*, **116**, 447-453. http://dx.doi.org/10.1104/pp.116.2.447

[39] Koide, R.T. and Kabir, Z. (2000) Extraradical Hyphae of the Mycorrhizal Fungus *Glomus intraradices* Can Hydrolyse Organic Phosphate. *New Phytologist*, **148**, 511-517. http://dx.doi.org/10.1046/j.1469-8137.2000.00776.x.